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Soybean Cyst Nematode Race Test: Do You Really Need One?

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Soybean cyst nematode, *Heterodera glycines*, is a microscopic, unsegmented plant-parasitic roundworm that attacks the roots of soybeans. Many plant-parasitic nematodes are believed to be native to the United States, but soybean cyst nematode likely was introduced into the United States from Japan. Soybean cyst nematode was first discovered in the United States in 1954 in North Carolina (Winstead et al., 1955) and since has spread to 26 additional states in the Southeast and Midwest (Figure 1) (Noel, 1992). The nematode was first discovered in Iowa in Winnebago County in 1978. More than 70% of approximately 400 randomly selected Iowa fields

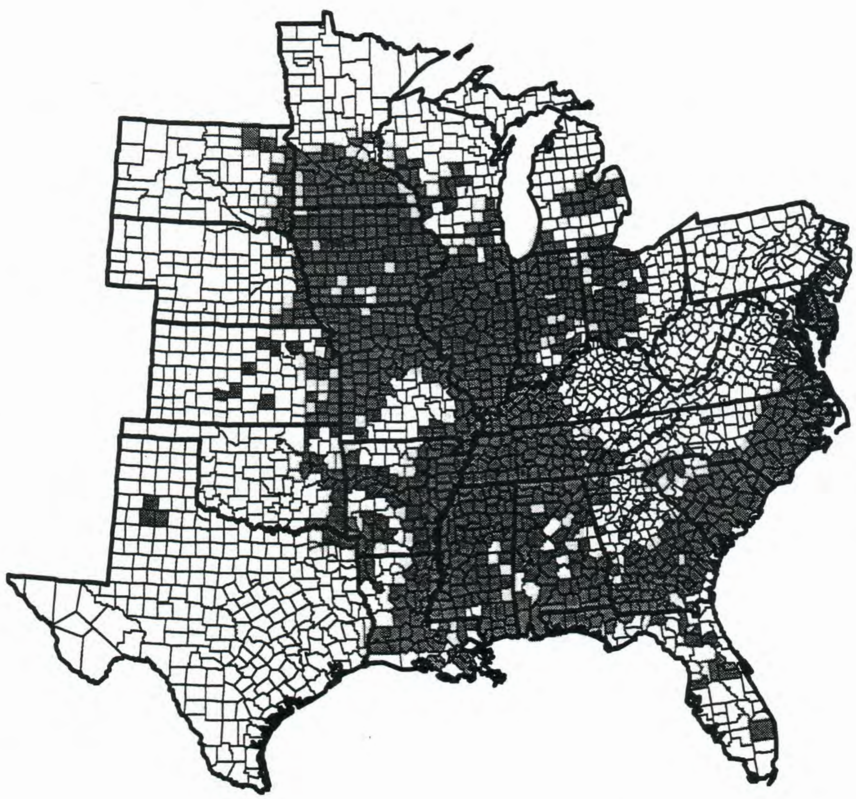

Figure 1. Known distribution of SCN in the United States in 1999 (known infested counties are shaded in gray).

sampled in 1995 and 1996 were infested with the nematode (Workneh et al., 1998). This nematode is a widespread and serious threat to profitable soybean production throughout the Midwest.

Life Cycle of Soybean Cyst Nematode

The soybean cyst nematode life cycle has three major stages: egg, juvenile, and adult. The life cycle can be completed in 24 to 30 days under optimum conditions in the summer. Consequently, two to four generations per growing season are possible in the Midwest. Worm-shaped soybean cyst nematode juveniles hatch from eggs in the soil when adequate temperature and moisture levels occur in the spring (Schmitt and Riggs, 1989). These juveniles are the only life stage of the nematode capable of infecting soybean roots. Hatched juveniles that do not penetrate host roots and begin feeding will die from starvation, predation, or parasitism within several days to a few weeks.

After penetrating the soybean roots, juveniles move through the root until they contact the vascular tissue. There they cease moving, lose most of the muscles in their bodies, and begin to feed. In order to feed, the nematodes inject secretions that modify root cells and transform them into specialized feeding sites called syncytia. As the nematodes feed, they swell. Eventually the female nematodes become so swollen that they break out through the root tissue and are exposed on the surface of the root. Male nematodes, which are not swollen as adults, migrate out of the roots into the soil and fertilize the lemon-shaped adult females on the roots. After fertilization, males eventually die whereas females remain attached to the roots and continue to feed. The swollen females begin to produce eggs, initially in a mass or egg sac outside the body and later within the body cavity of the female. The entire body cavity of the adult female eventually becomes filled with eggs, and the female dies. It is the egg-filled body of the dead female that is referred to as the cyst.

Cysts eventually will dislodge from the roots and become free in the soil. The walls of the cyst become very tough and provide excellent protection for the 200 or so eggs contained within. Soybean cyst nematode eggs survive within the cyst until conditions become proper for hatching. Although many of the eggs may hatch within the first year, many also will survive within the cysts for many years.

Management of Soybean Cyst Nematode

For all practical purposes, soybean cyst nematode never can be eliminated from a field once it is present. However, there are things that can be done to manage the nematode in order to maximize soybean yields and minimize reproduction of the nematode.

Effective management of soybean cyst nematode involves a three-prong approach comprising scouting for early detection of infestations followed by proper use of resistant soybean varieties in rotation with nonhost crops in infested fields. One of the more confusing aspects of soybean cyst nematode management is the issue of races as it relates to resistant soybean varieties.

The Soybean Cyst Nematode Race Scheme

The existing race concept was developed at a meeting of scientists involved with soybean cyst nematode research and management in Beltsville, Maryland, in December 1968 (Golden et al, 1970). The meeting was held to discuss, among other topics, the discovery of soybean cyst nematode populations that were capable of reproducing on the newly released soybean cyst nematode-resistant soybean varieties. This group of scientists adopted the term "race" for these subspecific nematode populations, they established a set of guidelines to use to determine race identity, and they described four soybean cyst nematode races (Golden et al, 1970). Nearly two decades after publication of the initial soybean cyst nematode race scheme, Riggs and Schmitt described the identity of and gave numerical designations to all 16 races that are possible using the aforementioned race scheme (Riggs and Schmitt, 1988).

To conduct a race test, eggs are extracted from cysts of soybean cyst nematode. The eggs are used to inoculate seedlings of five soybean lines designated as the soybean cyst nematode race differential lines. The soybean cyst nematode race differential soybean lines comprise one standard susceptible variety (Lee) and four resistant soybean lines (Peking, Pickett, PI 88788, and PI 90763). Inoculated plants generally are incubated for a period of four weeks, and then the number of females produced on the root system of each seedling is counted. A "female index" is calculated by dividing the average number of females produced on a resistant race differential soybean line by the average number of females produced on the susceptible race differential soybean line. If the female index value is less than 10, the nematode population is scored as "–" on that particular differential soybean line. Conversely, if the female index is greater than or equal to 10, the nematode population is considered as "+" on the differential soybean line. The scientists who developed the soybean cyst nematode race test scheme believed that 10% reproduction on a resistant soybean line would allow for a nematode population to increase "quickly" on a resistant soybean variety (Riggs, 1988), thus a value of greater than or equal to 10 was used to designate successful reproduction on a soybean line. It is the combination of "+"s and "–"s on the four resistant race differential soybean lines that determines to what numerical race class a nematode population is assigned (Table 1).

Problems With the Soybean Cyst Nematode Race Scheme

Although the soybean cyst nematode race scheme developed in 1968 (Golden at al, 1970) apparently worked well for characterization of populations of the nematode for many years, there are many problems currently associated with use of the race scheme. The difficulties associated with trying to use the soybean cyst nematode race testing scheme can be attributable to two types of problems – biological problems and practical problems.

Biological problems

The soybean cyst nematode race scheme attempts to assign populations of the nematode to discrete categories of "+" or "–" based on their ability to reproduce on the race differential soybean lines. However, the number of females produced on each soybean line is a continuous variable, and it is not valid to convert such a numerical value to a "+" or "–" based on the arbitrary "10% rule" of female index values. Further difficulty arises from the fact that it is not possible to test an individual soybean cyst nematode on all of the race differential soybean lines.

Table 1. Reproduction of the 16 possible races of soybean cyst nematode on the four race differential soybean lines (Riggs and Schmitt, 1988).

	Reaction on resistant race differential			
Race designation	Pickett	Peking	PI 88788	PI 90763
1	–	–	+	–
2	+	+	+	–
3	–	–	–	–
4	+	+	+	+
5	+	–	+	–
6	+	–	–	–
7	–	–	+	+
8	–	–	–	+
9	+	+	–	–
10	+	–	–	+
11	–	+	+	–
12	–	+	–	+
13	–	+	–	–
14	+	+	–	+
15	+	–	+	+
16	–	+	+	+

Consequently, one has to use a sample of thousands of soybean cyst nematode individuals from a field for a race test, and sampling error can be a major cause of variation in the race test results. Also, because a race test is performed on a sample of a population of soybean cyst nematodes, the results of the test are a description of the sample and may not provide accurate information about the uniformity or parasitic ability of the overall nematode population in that field.

A third, major source of difficulty associated with using the soybean cyst nematode race scheme is that the race differential soybean lines contain multiple genes for resistance and do not differ by just a single gene. In fact, the four resistant race differential soybean lines likely have several resistance genes in common. Pickett obtained its resistance genes from Peking (Brim and Ross, 1966), but there are four races in the race scheme that are characterized as reproducing on Peking but not Pickett (races 11, 12, 13, and 16). How can Pickett have resistance genes that are not also present in Peking, a situation that must exist for nematode populations to be able to reproduce on Peking and not Pickett?

Practical problems

In addition to the biological problems with the soybean cyst nematode race scheme described above, there are some substantial practical problems that preclude use of the existing soybean cyst nematode race scheme in describing populations of the nematode or in developing meaningful management recommendations.

The results of a soybean cyst nematode race test can be affected by the conditions under which the race test determination is preformed. The temperature, source of nematode inoculum (eggs, juveniles, or cysts), amount of inoculum, and several other factors may affect the numbers of soybean cyst nematode females that form on the roots of the race differential soybean lines. To reduce this source of variability and error in the race-testing scheme, Riggs and Schmitt (1991) identified a set of optimized conditions under which soybean cyst nematode race testing should be conducted. However, the numbers of females that are produced on the race differential soybean lines, including the susceptible variety Lee, can vary by several hundred percent even when controlled and uniform inoculation and incubation conditions are used to conduct the race tests. For example, the average number of females produced on the susceptible race differential variety Lee by 46 different race 3 soybean cyst nematode populations from Minnesota ranged from 49 to 438 (Table 2).

Table 2. Summary of race test results from 61 Minnesota soybean cyst nematode populations (S. Chen, University of Minnesota, unpublished).

			Average female index				Reproduction on Lee	
race	#	%	Pickett	Peking	PI88788	PI90763	Avg. #	Range
1	8	13	4.4	0.5	18.1	0.0	108	60 – 201
3	46	75	2.4	0.3	2.9	0.3	140	49 – 438
4	1	2	32.4	18.5	27.5	12.7	52	– –
6	5	8	25.1	1.8	2.5	0.3	91	62 – 191
14	1	2	68.9	56.5	6.7	45.3	102	– –

The second major practical problem associated with using race designations to formulate management recommendations is that soybean breeders typically do not test soybean varieties that are being developed with soybean cyst nematode resistance against all races of the nematode. Virtually all of the soybean cyst nematode-resistant soybean varieties available for use in the upper Midwest have obtained their nematode resistance genes from either Peking or PI88788, two of the race differential soybean lines. PI 88788 is the more common type of resistance available in soybean varieties adapted for Iowa and the upper Midwest. Peking and PI 88788 each are resistant to eight SCN races; Peking is resistant to races 1, 3, 5, 6, 7, 8, 10, and 15 whereas PI 88788 is resistant to races 3, 6, 8, 9, 10, 12, 13, and 14 (Table 1). However, soybean varieties with soybean cyst nematode resistance derived from Peking commonly are advertised in soybean seed sales literature as resistant only to race 3 or to races 1 and 3. Similarly, soybean varieties with soybean cyst nematode resistance from PI 88788 usually are advertised as resistant only to races 3 and 14 (sometimes erroneously listed as race 4).

It is unfortunate that the soybean cyst nematode-resistant soybean varieties are advertised as resistant to only a few soybean cyst nematode races, but there are at least two reasons for this. First, soybean cyst nematode-resistant soybean varieties typically are evaluated for resistance to only a few soybean cyst nematode races (1, 3, and, sometimes, 14) because keeping pure cultures of numerous soybean cyst nematode races is extremely difficult and testing for resistance to multiple nematode races is very labor intensive. Race 3 is the most common soybean cyst nematode race in Iowa (and many other states, as well – see Table 2), so virtually all resistant soybean varieties are tested for resistance to this race. Consequently, varieties with Peking-derived resistance typically are advertised as resistant to race 3, or maybe races 1 and 3 if the seed company had the resources to test the variety against race 1 and 3 of nematode. Those soybean varieties with soybean cyst nematode resistance derived from PI 88788 usually are advertised as resistant to race 3, or races 3 and 14 if the seed company tested the variety against soybean cyst nematode races 3 and 14. Certainly, one cannot assume that every soybean cyst nematode-resistant soybean variety that obtained its resistance from PI 88788 is resistant to all of the eight soybean cyst nematode races that PI 88788 is resistant to because the soybean varieties may have not received all of the resistance genes from PI 88788 during the variety breeding process. The same holds true for varieties with soybean cyst nematode resistance derived from Peking. Nevertheless, it is quite possible that any variety with verified resistance to race 1 or 3 or 14 of the soybean cyst nematode also has resistance against other races of the nematode.

The second reason that the soybean cyst nematode-resistant soybean varieties are advertised as resistant to only a few soybean cyst nematode races is that soybean cyst nematode resistance is very strictly defined as 90% or more suppression of soybean cyst nematode reproduction relative to reproduction on the standard soybean cyst nematode-susceptible soybean variety, Lee. So, for example, a soybean variety that consistently suppresses 80% on the reproduction of a particular soybean cyst nematode race, technically, is not considered resistant to that race of the nematode. Clearly, such a variety would be quite useful for a grower with a field infested with that particular soybean cyst nematode race. Until recently, there was no standard way to indicate that some soybean varieties were capable of suppressing reproduction of soybean cyst nematode by 70% or 80%. Within the past several years, though, it has become generally acceptable for soybean varieties with 60% to 90% suppression of soybean cyst nematode reproduction to be characterized as "moderately resistant" to a particular soybean cyst nematode race (Schmitt and Shannon, 1992). Still, most seed companies today do not test soybean varieties for resistance to more than soybean cyst nematode races 1, 3, and 14.

So, if you happen to have a race test done on your field and you are informed that you have a race of soybean cyst nematode that is not listed among the available resistant soybean varieties (like race 5 or 7), are there no resistant varieties available for you to use? Not necessarily. A soybean cyst nematode-resistant soybean variety with resistance to race 3 likely will suppress the reproduction of a race 7 soybean cyst nematode population enough to increase soybean yields and prevent a buildup of the nematode. In other words, soybean cyst nematode-resistant soybean varieties provide some “cross protection” against races other than those to which the varieties are listed as resistant. Figure 2 contains field data from Missouri where the yield of a race 3 soybean cyst nematode-resistant soybean variety was 26 bushel per acre greater than that of a soybean cyst nematode-susceptible variety in a field infested with race 5 of the nematode. Clearly, the race 3 resistance of the soybean variety provided protection against race 5 of the nematode.

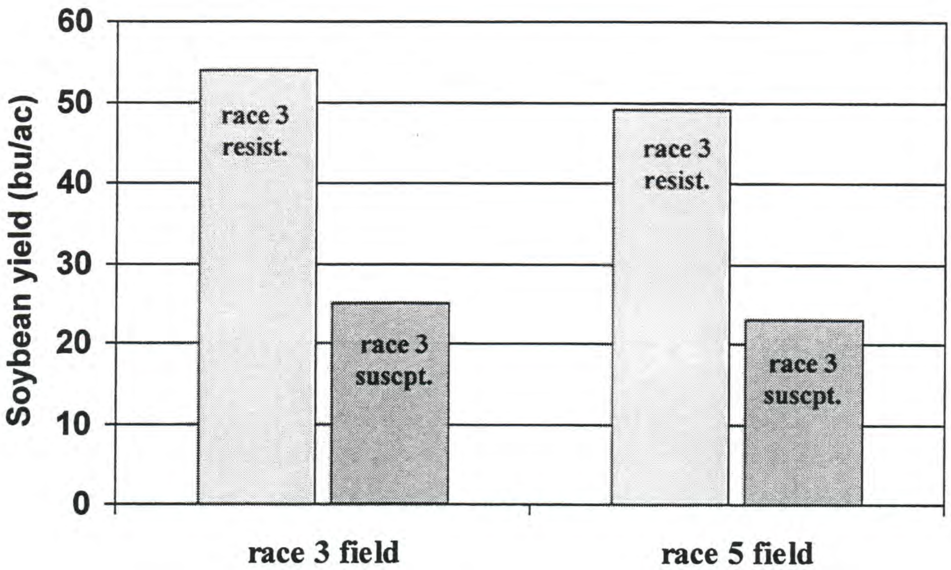

Figure 2. Yield of a race 3 soybean cyst nematode-resistant soybean variety and a susceptible soybean variety in fields infested with race 3 and race 5 of the soybean cyst nematode (T. Niblack, University of Missouri, unpublished).

Summary

The soybean cyst nematode race scheme was developed more than 30 years ago in response to the discovery of nematode populations that could reproduce on the first soybean cyst nematode-resistant soybean varieties that were released. The race typing may have worked well in the years immediately after the development of the concept. However, much scientific evidence has been collected in the past few decades to indicate that the current method of race determination does not provide consistently useful information about the parasitic behavior of the nematode population. Additionally, screening resistant soybean varieties for resistance against only a few common soybean cyst nematode races makes the race typing system of very limited utility. For soybean growers and agribusiness professionals who advise growers, the "bottom line" is you do not need to have a perfect match of soybean cyst nematode race with soybean resistance to suppress the nematode and to obtain increased soybean yields in soybean cyst nematode-infested fields – it is not a simple "all or nothing" situation. Thus, the answer to the question posed in the title of this presentation – do you need a soybean cyst nematode race test – is no.

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